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TEACHING SERIAL POSITION SEQUENCES TO MONKEYS WITH A DELAYED MATCHING-TO-SAMPLE PROCEDURE[1]

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Comparison was made of two methods for training monkeys to "observe" a two-member serial position sequence by pressing two consecutively lighted keys and then to "report" the sequence by pressing the same two keys in the same order but without the lights. A fading technique involving gradual elimination of brightness cues from "reporting" keys was found more effective than a no-fading procedure in which the cues remained bright during training and then were suddenly removed. Animals that failed to learn to report a new sequence with the no-fading procedure sometimes developed behavior incompatible with that desired. They made repeated and specific errors that prematurely terminated trials of the sequence to-be-learned, even though the correct key was cued by a bright light. They behaved appropriately, however, on succeeding trials of other sequences. Thus, the errors were followed by trials on which reinforcement occurred. Manipulation of this contingency indicated its importance in maintaining the stereotyped error patterns.

Many experimenters have demonstrated that the learning of such discriminations as size, form, color, *etc.* may be facilitated by "fading" techniques in which the terminal performance is approached slowly through graded stimulus changes (Terrace, 1963*a*, *b*; Schusterman, 1966; Ray, 1967; Sidman and Stoddard, 1967; Touchette, 1968). Fading procedures have also been useful in establishing more complex performances in humans, as in matching stimuli to a sample having the same shape, size, and color (Hivey, 1962) and degree of rotation (Moore and Goldiamond, 1964; Bijou, 1968).

Sidman and Rosenberger (1967) reported that fading procedures helped monkeys learn to press different keys in a fixed sequence, each correct key in the sequence being specified by its location (serial position sequences). The animals learned a longer serial position sequence when brightness cues for the correct serial responses were faded out gradually rather than eliminated suddenly. Boren (1969*a*) also found that acquisition of serial position sequences was facilitated by fading. Since the animals in these and other studies (Polidora, 1963; Boren and Devine, 1968) had to respond to the same serial position stimuli in every trial, the procedure was analogous to a simple discrimination learning task. Matching to sample, in contrast, requires the animal to respond to different stimuli in every trial.

Nothing is known about the teaching of serial position sequences to animals by means of matching-to-sample techniques. The present experiment investigated the use of a delayed matching-to-sample procedure to teach sequences to monkeys. The procedure was designed to teach the animals to "observe" a two-member sample by pressing two consecutively lighted keys and then to "report" or reproduce the sequence by pressing the same keys in the same order but without the lights. Although the animals had to learn only one new sequence at a time, other sequences were also scheduled so that a trial-to-trial mixture was obtained. A primary aim was to investigate the effectiveness of fading in the development of these complex discriminations.

The task was analogous to the digit span for humans. In the digit span, the subject must listen to and orally reproduce spoken numbers. Here, the stimuli were key positions, rather than numbers, and the animals had to press keys rather than vocalize.

METHOD

Subjects

Four rhesus monkeys were maintained at 80% of free-feeding weight throughout the ex-

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periments by restriction of their diet of 1-g banana pellets. When the animals did not receive the full diet during an experimental session, the remainder was given in the home cage at least 30 min after the end of the session. A vitamin supplement was also administered in the home cage.

Apparatus

The chamber in which the animals worked measured 2 by 2 by 2 ft (0.61 by 0.61 by 0.61 m) and formed part of a larger sound-resistant chamber. An aluminum wall separated the animal's space from the rest of the chamber.

A panel with eight sandblasted Plexiglas keys was mounted in the dividing wall. The keys were 1 in. (2.5 cm) square and were spaced 1.75 in. (4 cm) apart in a horizontal row. They were located 13.5 in. (34 cm) from the floor of the animal's space. A compartment behind each key contained two blue 7.5-w Christmas tree bulbs for key illumination and a micro-switch that was operated by a key press. A houselight was mounted at the top of the dividing wall.

A food tray that could be lighted from behind was set 8 in. (20 cm) below the center of the panel containing the response keys. "White noise" in the experimental space masked extraneous sounds during experimental sessions.

A solid-state circuit controlled the scheduling of stimuli, the delivery of reinforcers, and the setting of the potentiometers that determined key brightness. A Kodak Carousel slide projector and a 4 by 6 matrix of photocells arranged the sequences of correct keys (Mackay, 1969). Each slide in the slide tray arranged one sequence. Use of the zero position of the standard 80-slide tray allowed continuous recycling of a series of 81 sequences.

A 20-pen Esterline-Angus operations recorder continuously monitored the selection of correct keys, the animal's responses and changes in key illumination.

Initial Training and General Procedure

Initial training proceeded in several steps. Pressing single lighted keys was shaped following magazine training. A press on a lighted key turned the keylight off and was followed by a 2-sec period during which a food pellet was delivered, the food tray was illuminated, a tone sounded, and the houselight was turned off. Next, reinforcement occurred only after the animal had pressed a set of four keys, lighted one at a time. Each such set of presses counted as one correct trial. In the final stage of initial training, a variable-ratio schedule for food delivery was built up to an average of one pellet per four correct trials. The other events (lighted tray, *etc.*) continued to follow each correct trial.

Figure 1 provides a schematic illustration of a group of trials that might be scheduled in initial training. It introduces terminology and illustrates further aspects of the general procedure. The first two trials depict correct trials; keys were pressed in the order 1-4-1-4 (first trial), and 7-6-7-6 (second trial). In each trial, the same sequence of correct keys scheduled for members A and B (*e.g.*, 1-4 in trial 1, 7-6 in trial 2) was also scheduled for members C and D. The correct keys for members A and B were always fully bright (120 v). These two members will be referred to also as the *observing phase* of a trial; the *reporting phase* will denote members C and D. The brightness of the correct keys scheduled at members C and D could vary from fully bright to off. (Only fully bright correct keys are shown in Fig. 1.) Manipulation of the brightness cues at members C and D constituted a critical experimental operation.

An error, *i.e.*, a press on any of the seven keys not scheduled as correct at a given member, terminated the trial and started a 5-sec timeout during which the house and keylights were off. Thus, opportunities to press later members in a trial followed only correct presses at preceding members. In the third trial in Fig. 1, keys 4 and 8 were pressed correctly at members A and B, but at member C an incorrect press (indicated by the arrow) initiated the timeout rather than member D.

A key press during the timeout prolonged it. The next trial began only after a 5-sec period with no key presses.

The sequences changed from trial to trial even after an error (non-correction). Thus, as shown in Fig. 1, a series of trials might be scheduled with key sequences 1-4, 7-6, 4-8, 3-2, *etc.*

The Sequences and Pre-Training Requirements

In any training session, one sequence was the critical sequence to be learned. Other sequences were scheduled in addition, however,

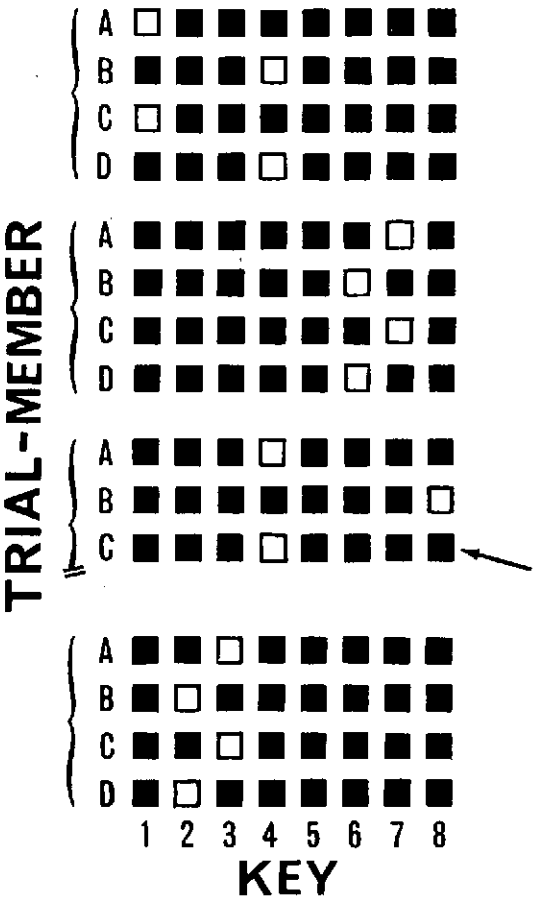

Fig. 1. Schematic illustration of the eight-key response panel in successive members (A, B, C, D) of four trials (indicated by brackets). The first trial is at the top. Open squares represent fully bright keys; filled squares dark keys. The arrow at member C of the third trial indicates an error press on key 8. See text for additional details.

to permit the mixing of sequences from trial to trial. These other sequences will be called baseline sequences because they provided a baseline of ongoing behavior that permitted the detection of interference effects due to training with the critical sequence.

The animals were treated in two pairs. When the data for the present study were collected, each pair was at a different stage of training.

Monkeys R^{28} and R^{37}. These animals were introduced to the experimental procedures immediately after initial training. The same four sequences were scheduled in every session. In each experimental session, one of the four sequences was designated as the critical sequence (the order of use is shown at the lower right in Table 1) and was treated as described below; the remaining three sequences (shown at the lower left in Table 1) served as a baseline and always had a fully bright correct key in each member (like Fig. 1). Each of the four sequences appeared equally often during a session. At the beginning of each session, the animals were required to complete 12 consecutive correct trials with all four sequences scheduled and each correct member in each trial fully bright (like Fig. 1).

Monkeys R^{1} and R^{20}. These animals had served in a pilot study in which they had already learned to observe and then report some sequences with dark keys in trial members C and D. These sequences, listed at the upper left in Table 1, were used as a baseline in the present study. Accurate performance with the previously learned sequences was verified before introducing any new stimulus sequence; for two successive days, correct reporting was required in at least 90% of 162 trials without brightness cues in the reporting phase (like the two trials heading each column in Fig. 2). An introductory requirement in these baseline-verification sessions was 12 consecutive correct trials with fully bright correct keys (like Fig. 1).

In addition to these baseline-session criteria, the animals had to meet the following prelim-

Table 1

Baseline and critical sequences scheduled for four animals. The order in which the critical sequences were used is shown. Different combinations of the baseline and critical sequences for Monkeys R28 and R37 are indicated.

Subjects	*Baseline Sequences*	*Critical Sequences*
Monkey R1	1-4; 4-1; 4-8; 8-4; 3-2; 7-6	1. 7-1 2. 2-8
Monkey R20	1-4; 4-1; 4-8; 8-4; 3-2; 7-6; 8-1; 1-8	3. 5-2
Monkeys R28 and R37	1. 1-3; 4-2; 8-6 2. 1-3; 5-7; 8-6 3. 4-2; 5-7; 8-6	1. 5-7 2. 4-2 3. 1-3

inary requirements at the beginning of every training session; (1) 12 consecutive correct trials with baseline sequences only and fully bright correct keys in each member (like Fig. 1); (2) 12 consecutive correct trials of baseline sequences but with dark keys in the reporting phase (like the two trials heading each column in Fig. 2); (3) 12 consecutive trials that included baseline trials without brightness cues at members C and D and critical-sequence trials with a fully bright correct key in each member (like column B in Fig. 2). Members C and D of baseline trials remained dark for the rest of the session.

A critical sequence was scheduled on one third of the trials in a teaching session; equal numbers of the baseline sequences constituted the remainder. After a critical sequence was learned it was dropped from the set. The upper right side of Table 1 shows the order in which the three critical sequences were taught.

Pre-test. At the beginning of the first session involving a new critical sequence, a pre-test was given to confirm the necessity for teaching. The pre-test consisted of five presentations of the critical sequence mixed with presentations of baseline sequences. At members C and D of the five critical-sequence trials, the brightness cues were off. A test trial on one critical sequence is illustrated in Fig. 2 (Test, third trial).

Training

Two training procedures were used to teach the animals to reproduce new sequences on dark keys (members C and D). One animal from each pair (Monkeys R20 and R37) received procedure A (fading) with the first critical sequence to be learned; in the reporting phase of trials with the critical sequence, brightness cues that were superimposed on the serial position cues (*cf.* Sidman and Rosenberger, 1967) were gradually faded out as de-

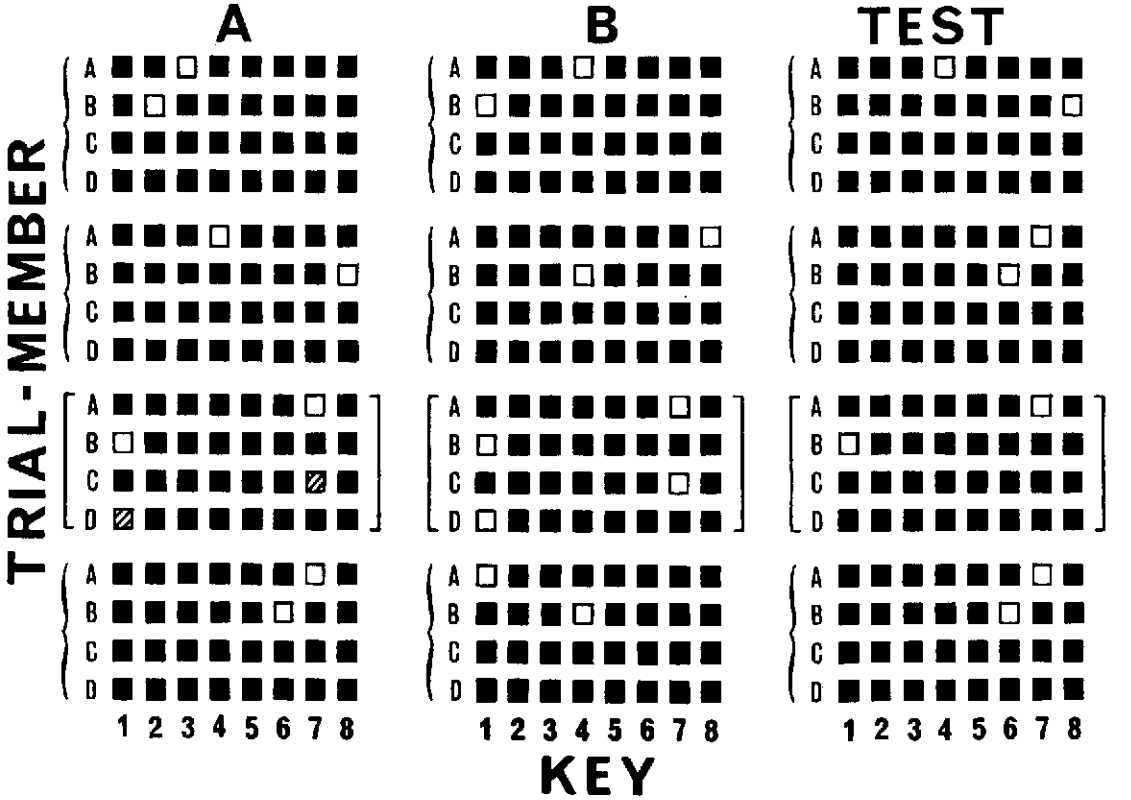

Fig. 2. Schematic diagrams of the eight-key response panel illustrating various conditions of the correct key-lights scheduled at trial members A, B, C, and D in different segments of sessions. Open squares represent fully bright keys; filled squares, dark keys. Keys in the fading state are crosshatched (column A, trial 3, members C and D). Trials with the critical sequence 7-1 are enclosed in square brackets. The other trials show uncued baseline trials scheduled for Monkeys R1 and R20. (Note: baseline trials for Monkeys R28 and R37 had a fully bright key in each member.) See text for additional information.

scribed below. The other animals (Monkeys R1 and R28) started with the control procedure (B, no fading) in which the lights remained fully bright during training. The order of the fading and control procedures then alternated for successive critical sequences with a given animal. An animal advanced to a new critical sequence only after it had learned to reproduce the preceding critical sequence on dark keys. Thus, if an animal failed to learn to report a given sequence with the control procedure, fading was instituted with the same sequence before a new sequence was introduced.

Procedure A. Fading. With this procedure, stepping-motor-driven potentiometers controlled the brightness of the correct keylights at members C and D of trials with the critical sequence; 32 voltage levels (fading steps) were used. Limit switches set the maximum output of the potentiometers at 95 v and the minimum at 10 v. At the highest level the lights were dimmer than in the fully-bright condition; at the lowest level no keylight was apparent to the experimenter.

On the first trial of the critical sequence, the cue lights were set at the brightest fading step. When the animal pressed a cued key correctly, the brightness of the key at that member was faded out by one step. Thus, in a fading trial with the critical sequence 7-1 (Fig. 2A, third trial), correct presses in members C and D caused keys 7 and 1 to appear one step dimmer on the next fading trial (not shown in Fig. 2). Whenever the animal pressed an incorrect key, the trial terminated and the brightness of the correct key in that member was increased by two steps for its next presentation. Thus, if the animal pressed key 6 instead of key 7 at member C, the error occurred in the initial member of the reporting phase; on its next appearance, key 7 at member C was two steps brighter.

The fading continued until the keylights at members C and D were fully faded for 10 successive trials of the critical sequence. If the animal failed to satisfy this criterion within 60 min, the session was terminated and repeated two days later with the same sequence.

Procedure B. No fading. In contrast to being eliminated gradually, lights were always fully bright on the correct keys at members C and D of critical-sequence trials (Fig. 2B, third trial). The keys remained fully bright until the animal had completed the same number of correct trials that would have ended fading (42 minimum).

Test. Immediately after training with either of the procedures was successfully completed, a test segment was added to indicate whether the animal had learned to report the new sequence. As shown in the example of Fig. 2 (TEST, third trial), the brightness cues were off in members C and D of all critical-sequence trials.

The test segment of a session ended after 10 successive correct trials with the critical sequence or 60 min after the start of the test. If the test segment ended because of time, the entire training session was repeated two days later with the same critical sequence. These additional training sessions (fading or no fading) were given every second day until the animal's test performance indicated that it had learned to report the sequence.

RESULTS

Pre-test performance. Monkeys R1 and R20 made errors in all of the pre-test trials with sequences 7-1, 2-8, and 5-2. Monkeys R28 and R37 made errors in all pre-test trials of the sequences 5-7, 4-2, and 1-3. These pre-test performances verified the need to teach the sequences to the animals.

Comparison of teaching procedures. The design of this experiment yielded two major ways of evaluating the effectiveness of the two teaching methods. First, matched pairs of animals were given the same sequence to learn; one animal had brightness cues that were attenuated by fading and the other animal had brightness cues but no fading. Comparison of the test performance of the two animals permitted assessment of the effectiveness of the two procedures. Second, it was possible for both procedures to be scheduled with the same sequence for a single animal. Differential effectiveness of the two procedures could be demonstrated if an animal, after having failed to learn with the first procedure scheduled, was successful with the second method. Both inter- and intra-subject comparisons indicated the superiority of the fading procedure.

1. *Fading vs. no fading: matched animals.* Table 2 shows the number of sessions, training trials, and test trials received by each animal and indicates whether or not the animal satis-

Table 2

Performance on each critical sequence presented to each of four animals. A plus (+) indicates that the accuracy criterion was satisfied. A minus (−) denotes failure to meet that criterion. The three entries for each sequence under a given procedure are as follows: 1. total teaching trials; 2. total test trials; 3. number of sessions.

	Procedure			
	No Fading	*Fading*	*No Fading*	*Fading*
Sequence	*Monkey R1*		*Monkey R20*	
7-1	1. 420 −2. 1242 3. 10	1. 257 +2. 172 3. 3		1. 190 +2. 20 3. 2
2-8		1. 430 +2. 325 3. 5	1. 420 +2. 1000 3. 10	
5-2	1. 378 +2. 905 3. 9			1. 44 +2. 25 3. 1
	Monkey R28		*Monkey R37*	
5-7	1. 504 −2. 943 3. 12	1. 546 +2. 84 3. 6		1. 802 +2. 124 3. 8
4-2		1. 111 +2. 50 3 1	1. 336 +2. 806 3. 8	
1-3	1. 84 −2. 192 3. 2	1. 59 +2. 23 3. 1		1. 57 +2. 15 3. 1

fied the desired performance criterion. With fading, the animals learned all six critical sequences and required fewer total trials than were given to their no-fading partners. Three sequences (5-2, 4-2, 1-3) were learned by fading in a single session. Without fading, the animals learned only three of the six sequences and required more sessions and more total trials (sequences 2-8, 5-2, and 4-2).

For four sequences (7-1, 5-2, 4-2, 1-3) the combined total of training (fading) and test trials per sequence was less than the number of training trials alone for the corresponding control animal. For the sequence 2-8, approximately the same number of training trials were scheduled with each procedure but the animal given the fading (Monkey R1) required many fewer sessions and many fewer test trials.

The sequence 5-7 provided the only instance in which the animal trained by the fading procedure (Monkey R37) received substantially more training trials than the control animal (Monkey R28). The table, however, is misleading in this instance; Monkey R28's training was terminated earlier than it otherwise would have been because the animal developed behavior incompatible with reporting. It made errors in the observing phase of more than 70% of test trials in Sessions 8 through 12; since errors terminated the trial, such observing errors precluded the opportunity to report the sequence. No-fading training of Monkey R1 with the sequence 7-1 was terminated for the same reason. An analysis of the observing-phase errors made by Monkey R28 is presented below (see Analysis of observing-phase errors) together with additional data obtained from Monkey R1 after completion of the present experiment.

In the third instance in which no-fading training was terminated before the new sequence was learned, Monkey R28 received only two sessions of training with the 1-3 sequence. The animal made errors in every test trial in the two sessions.

2. *Fading* vs. *no fading: same animal.* The desired performance was established by the fading method in each sequence where it had

not been acquired without fading (Monkey R1, sequence 7-1; Monkey R28, sequences 5-7 and 1-3). Again fewer trials were required with fading. Monkey R28 learned the sequence 1-3 in a single session.

Performance with previously learned (baseline) sequences. (Monkeys R1 and R20.) Monkey R1 often made errors in baseline trials during the first five sessions of no-fading training with the critical sequence 7-1. The animal was correct in only 27% of trials of the sequence 4-1 during the training segment of Session 2, and in only 40% of these trials in the test segment of Session 3. Other sequences, also briefly but less severely affected (at least 67% correct), were 4-8 and 8-4. These errors disappeared with continued training so that during Sessions 6 through 10, more than 90% of the trials of each of the six previously learned sequences (1-4, 4-1, 4-8, 8-4, 3-2, 7-6) were correct. The critical sequence (7-1), however, was not learned.

In the first session in which fading was applied in teaching the 7-1 sequence, Monkey R1 again made errors with the old sequences. Only 78% and 65% of the trials with sequences 4-1 and 1-4 respectively were correct, but the sequences 4-8, 8-4, 3-2, and 7-6 were reported correctly on at least 90% of the trials. The errors also occurred in the second session of fading but only in the test segment. No difficulty was apparent in the third session when the animal did learn the 7-1 sequence.

The animal's errors fell at a different member in trials of the two baseline sequences 4-1 and 1-4. In trials of the sequence 4-1, it pressed the bright keys 4 and 1 of the observing phase and then made an error at member C when the keys were dark. In trials of the sequence 1-4, the animal responded correctly on the lighted first and second members, pressed the dark key 1 at member C but then made an error at member D. The learning of the 7-1 sequence interfered at the point in the baseline sequences when an uncued reporting member followed a key-1 press. Key 1 was the common element in the three sequences.

A similar temporary disruption of previously accurate responding occurred while Monkey R1 was learning the critical sequence 2-8. Now, the sequences affected were 4-8 and 8-4. The errors were in the initial member of the reporting phase with the sequence 4-8, but in the final member with the sequence 8-4. In this instance, the new sequence (2-8) interfered with baseline sequences at the point when an uncued reporting member followed a key-8 press.

Acquisition of the critical sequences 7-1 and 2-8 also disturbed the previously accurate behavior of Monkey R20. The disturbance appeared with sequences 1-8 and 8-1, which were absent from the set scheduled for Monkey R1. There was only little disturbance in the baseline of either of the two animals during acquisition of the 5-2 key-sequence.

In summary, the acquisition of some new sequences by Monkeys R1 and R20 lowered the accuracy of specific but different sequences in each animal's baseline. Errors did not occur on all baseline sequences where they might have been expected. For example, during training on the 7-1 sequence, both animals maintained accurate performance on the baseline sequence 7-6 but they made errors on other baseline sequences. The reason for these differential effects is not clear at present.

Analysis of Observing-Phase Errors

In two instances noted above (Monkey R28, critical sequence 5-7; Monkey R1, critical sequence 7-1), animals frequently terminated test trials by making errors in the brightly cued observing phase, and thus precluded the opportunity to report the sequence. In contrast, the animals correctly reported at least 90% of the baseline trials in each session. The animals' errors were systematic and depended on particular relations that developed among the stimuli, responses, and reinforcement when the training procedure failed to generate the appropriate behavior for reporting the critical sequence.

In 12 sessions, Monkey R28 made errors on 99% of the 943 test trials of critical sequence 5-7. Figure 3 shows that errors in the observing phase increased steadily over sessions. Such errors occurred in more than 70% of the test trials scheduled in each of Sessions 8 through 12. Errors in the reporting phase, although preponderant in early sessions (1 to 6), became restricted later to trials at the start of the test segment.

Figure 4 shows that by Session 12, Monkey R28 terminated most critical trials with incorrect presses at member A. In earlier sessions (Sessions 1 to 7) the animal's errors were most often at member C, the beginning of the

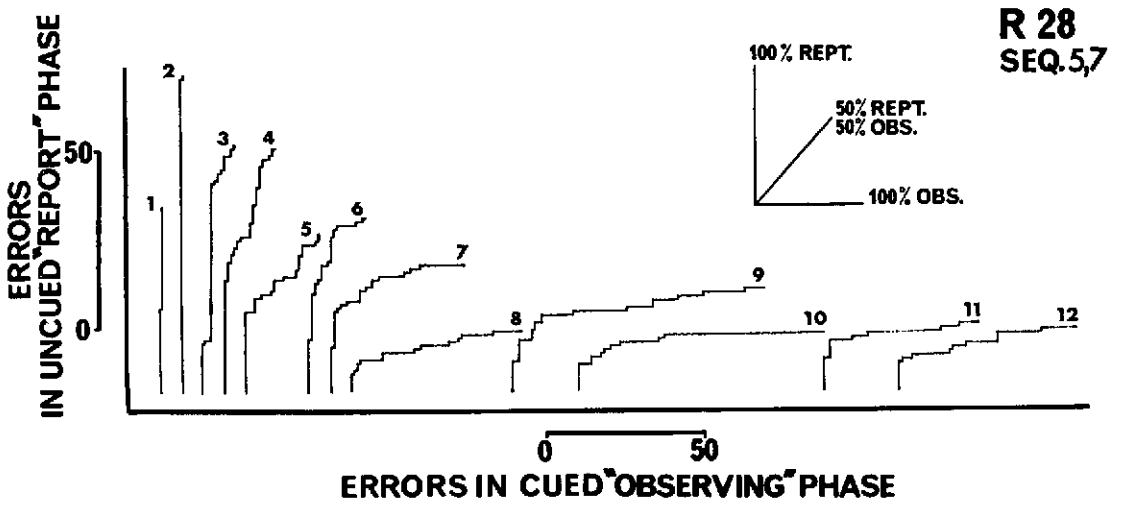

Fig. 3. Analysis of critical sequence errors made by Monkey R28 in 12 sessions. Each curve represents all errors made in a given session on the key-sequence 5-7 after removal of the brightness cues from the reporting phase of trials. Session 1 is at left. Errors in the reporting phase are stepped along the ordinate. Errors in the observing phase are stepped along the abscissa. The inset at the upper right shows three curves representing hypothetical relative frequencies of errors in the two phases.

uncued reporting phase. In Sessions 8 and 9, however, errors at the second cued member (B) became most frequent. Few trials reached member D in any session. Similar changes were observed within individual sessions.

Monkey R28 also tended to select a particular key when it made errors in trials of the sequence 5-7. In eight of the 12 sessions, total key-3 presses were equal to or greater than the total of all other incorrect choices in members A and B. By the final session, incorrect presses at member B became largely restricted to key 3 and the predominant member A errors to keys 2 and 3.

In trials of the other three sequences scheduled for Monkey R28, errors rarely occurred. None of these sequences, however, contained keys 5 or 7. Thus, the animal's stereotyped errors (keys 2 and 3) occurred on test trials of sequence 5-7, and became most common at the earliest member (A) in which the critical sequence could be discriminated from the baseline sequences.

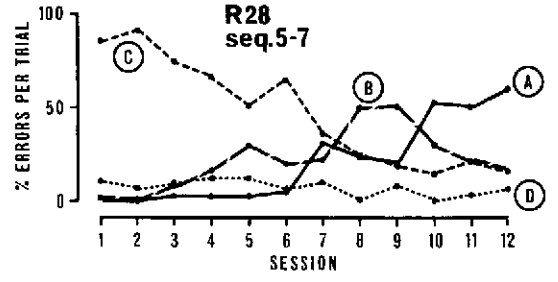

Fig. 4. Percentage of trials on which Monkey R28 made errors on members A, B, C, and D of the critical sequence 5-7.

During its original training with the sequence 7-1, Monkey R1, like Monkey R28, made errors that terminated test trials in the observing phase. The data presented here for Monkey R1 were obtained, however, in sessions scheduled after the animal had received all the training summarized in Table 2. Since no retention of the 7-1 sequence was found, additional training became possible. In five sessions using the no-fading procedure, the animal failed to report the sequence in 842 test trials. Figure 5 demonstrates that the animal's incorrect choices shifted, as with Monkey R28, from the reporting to the observing phase. By Session 5, Monkey R1 made observing-phase errors on 92% of the test trials. Unlike Monkey R28, however, it never made an error at the initial member (A). Instead, as Figure 6 shows, its errors concentrated at the second member (B). These errors were usually to key 8. In the fifth session, it selected key 8 instead of the bright key 1 on 91% of the test trials.

Since the critical sequence 7-1 and the baseline sequence 7-6 started with the same key, Monkey R1 could not discriminate these se-

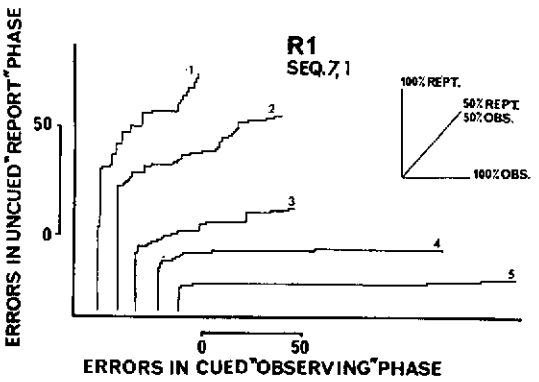

Fig. 5. Analysis of critical sequence errors made by Monkey R1 in five sessions. Each curve represents all errors made in a given session on the key sequence 7-1 after removal of the brightness cues from the reporting phase of trials. Session 1 is at the left. Errors in the reporting phase are stepped along the ordinate. Errors in the observing phase are stepped along the abscissa. The inset at the upper right shows three curves representing hypothetical relative frequencies of errors in the two phases.

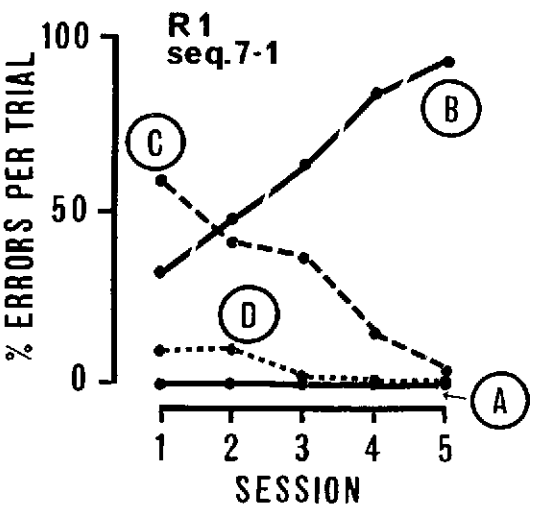

Fig. 6. Percentage of trials on which Monkey R1 made errors on members A, B, C, and D of the critical sequence 7-1.

quences until the bright key 7 was pressed and member B illuminated. More than 96% of trials with the sequence 7-6 were correct in each session. If, however, key 1 was illuminated after key 7, a key-8 press was highly probable, as described above. In addition, no errors were made when key 1 (member B of the critical sequence) was cued by a bright light in the baseline sequences 4-1 and 1-4. These and the other baseline sequences (4-8, 8-4, and 3-2) were accurately (90% correct trials) reported. Thus, like Monkey R28, Monkey R1's stereotyped errors were controlled by the particular cues in the observing phase of test trials.

To investigate whether the animals' stereotyped errors reflected a contingency in which the errors were reinforced by the appearance, in the next trial, of a baseline sequence likely to be correctly reported, the procedure was changed for three sessions with Monkey R1. In these sessions, training with the no-fading procedure was given as before. The test segment of these sessions, however, consisted of two parts. First, sequences changed from trial to trial, as before, until the animal had pressed key 8 instead of the bright key 1 at member B in a specified number of consecutive 7-1 trials (10, 5, and 10 trials in Sessions 1 to 3 respectively). Then, in the remainder of the session, the 7-1 sequence was repeated after each stereotyped key-8 error in order to eliminate the contingency suspected of maintaining these errors. The effects of all other responses were unchanged. In the three sessions, 66%, 85%, and 93% of 7-1 trials (190 or more in each session) were terminated by errors in the presence of the bright key 1. As shown in Table 3, however, the animal often chose key 6 in the second and third sessions. In addition, its baseline performance was virtually without error. The consequences of errors apparently affected the types of error that occurred.

Table 3

Incorrect choices of Monkey R1 in member B of the key sequence 7-1 expressed as a percentage of all member B errors. (Rounding errors accounts for session totals exceeding 100.)

	Key		
Session	*6*	*7*	*8*
1.	2	1	98
2.	44	6	51
3.	44	6	51

DISCUSSION

The present study confirms the superiority of the fading method for teaching response sequences but with a task that differed from that used by Sidman and Rosenberger (1967) and Boren (1969*a*). Their animals were trained on one sequence in a session that included no other sequences. In the present procedure, sets

of different sequences were used to permit the sequences to be changed from trial to trial. The present results thus provide evidence that monkeys can learn the complex discriminations involved in matching serial position sequences.

Only some of the animals in the present study learned to report sequences with the procedure in which the brightness cues were suddenly removed from the correct keys without fading. During the training, however, it was clear that the brightness cues controlled the responses of all the animals; errors were rare in training trials. Thus, reinforcement of the repeated sequence of presses on fully bright keys was not always sufficient to produce control of these responses by the appropriate serial position cues. It is possible, as Boren and Devine (1968) found, that the animals followed the brightly lighted keys in training trials but learned nothing about the sequence of responses that was to be acquired. Sidman and Rosenberger (1967), however, reported data indicating that limited acquisition was obtained when training with a brightly lighted sequence of keys was followed by an abrupt transition to the terminal condition without lights on the keys. Thus, the animals in the present study may have learned something from the training with fully bright cues which, in comparison with the fading, was then less effective in making contact with possible contingencies (reinforcement and extinction) in the test segment. The design of the present study, however, permitted no direct assessment of the effects of the different segments of the procedures used. Such an analysis would have required a control procedure in which all trials of the critical sequence were scheduled without cues in the reporting phase, *i.e.*, provided differential reinforcement only. Available data indicate only that such trial-and-error training results in poor acquisition when compared with fading procedures (Boren, 1969*a*).

Two animals developed systematic error behavior in the present study. These errors terminated trials prematurely and were thus incompatible with the desired performance. Although their responses were not those that the experimenter had specified in relation to the scheduled reinforcement, it was clear that the animals learned stimulus discriminations necessary for the desired performance. Their behavior was controlled by relevant stimuli, the cues provided in the observing phase of trials. In both instances, when the control procedure failed to teach the animals the appropriate serial responses for new sequences, the scheduling arrangements produced relations among stimuli, responses, and reinforcement that generated and maintained inappropriate behavior in trials with these sequences.

In studies of form and color matching with pigeons, Cumming and Berryman (1965 pp. 323-325) also obtained a mixture of appropriate and inappropriate behavior similar to that observed in the present study. They suggested that, in an adequate match-to-sample performance, the sample serves as an "instructional" stimulus; it acts as a selector of the simple discriminations whose S^Ds are the choice stimuli and "momentarily strengthens a particular discrimination." Applying this analysis to the stereotyped error behavior observed in the present study, it appears that, under some conditions, observing-phase stimuli failed to acquire the instructional function. Instead, these cues functioned as simple discriminative stimuli controlling specifiable responses that conflicted with the desired ones.

The stereotyped errors observed in the present study are not simply additional illustrations of previously described error patterns. Analyses of error patterns occurring with matching-to-sample procedures are rare (Cumming and Berryman, 1965). Most previous data were obtained with discrimination procedures (Miles, 1965; Sidman and Stoddard, 1967; Boren and Devine, 1968; Touchette, 1968; Boren, 1969*b*). In these cases, subjects often did not learn the specified discrimination but adopted other systematic patterns of responding that were influenced by features of the apparatus and procedures used. Thus, response to position cues, *e.g.*, the key on the right, the previous correct key, often produced a frequency of reinforcement sufficient to maintain position habits. These responses, however, unlike the behavior observed in the present study, reflected control by stimuli other than those designated as relevant by the experimenter. Analyses of such behavior are often treated as interesting but relatively unimportant byproducts of particular techniques. Systematic investigation of conditions that commonly yield particular types of errors are of theoretical and practical importance,

however. Such studies contribute to our understanding of variables involved in the particular procedures themselves and also suggest other procedures that might be used to alter or eliminate inappropriate behavior once it had appeared.

It should be noted that only small sets of sequences were used in the present study and no explicit attempt was made to maintain new sequences after the animals learned them. Indeed, they may have learned only the specific sequences used, rather than the generalized performance of observing and reporting sequences. This conclusion is supported by the animals' failures in pretest trials with new sequences and by the nature of the errors that appeared in the baseline performance of two animals (Monkeys R1 and R20) during their acquisition of new sequences. Such specific learning has been found in the development of other complex performances (Kelleher, 1958; Cumming and Berryman, 1961; Ferster and Hammer, 1966). It is possible that a generalized performance might ultimately emerge from the learning of successive, additional, single sequences. The present results indicate, however, that further exploration of factors involved in generating a generalized performance is required.

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